ASSESSING THE ENVIRONMENTAL LITERACY OF INTRO ENVIRONMENTAL SCIENCE STUDENTS

By

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Thesis directed by Bryan Shao-Chang Wee

ABSTRACT

Using an assessment tool, tailored to the Colorado academic science standards, a study was conducted to evaluate the environmental literacy of postsecondary, nonscience majors. Data were collected from 144 students taking an introductory environmental science class. A 16-item, multiple-choice question, environmental knowledge assessment instrument covered environmental content across three subdomains in the Colorado academic science standards: Physical Science, Life Science and Earth Systems Science. Population total mean scores were compared to sub-domain scores to assess students' overall environmental literacy as well as to identify the populations' weaknesses between the sub-domains. Results showed that the total mean score for the class was 52.18%, which indicates that the population as a whole does not have a strong foundation in environmental science nor high levels of environmental literacy and need further assistance in one or more of the three sub-domains. Statistical analysis revealed that on average the students scored a 67.8% in Physical Science, 53.4% in Life Science, and 37.8% in Earth Systems Science. Given that the findings were limited to environmental knowledge within the Colorado science standards, an assessment of environmental knowledge in social science standards, including measures of behavior, attitudes and dispositions toward the environment is warranted.

Keywords*: assessment; environmental education; environmental literacy; environmental science; environmental knowledge; Colorado State Science Standards*

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1. Prologue

Currently, there is not research being conducted on state content standards and how they relate to environmental literacy. Although we have created exceptional environmental frameworks and tools for measuring environmental literacy, the assessments are disconnected from the academic standards. It is not rational to expect any educator to stray from the academic standards they have been given by the state to follow a separate environmental literacy plan. Unfortunately, the all too common attitude is that, if it will not be tested, it will not be taught. If we want to measure environmental literacy of students, we must draw from what they are actually being taught. Environmental knowledge, of natural and human systems, has been incorporated into the Colorado Science Standards. Why not use these same standards as a baseline for the environmental assessment? It only makes sense.

The proposed research examines Intro to Environmental Science students and their understanding of environmental science knowledge and concepts. The research seeks to answer the question: Do post-secondary students possess the environmental knowledge they were taught in Kindergarten through twelfth grade (K-12)? Having a clear understanding of the foundational concepts, such as the interaction of natural and human systems, is an important aspect of environmental literacy. Once the more quantitative foundational concepts are understood, this enables the educator to instruct from a more qualitative angle. This approach is known as the T-educational approach (Golley, 1998). The arms are broad and the stem deep. The ultimate goal of Intro to Environmental Science is to grow individuals with operational environmental literacy. The measured, foundational knowledge highlights normal and memorable patterns of environmental relationships and organization of observations, interpretations and generalizations. The research includes the use of an assessment tool, AELIESS, created using the new Colorado Department of Education K-12 Academic Standards. The research supplies environmental educators with a practical assessment tool.

2. Introduction to Literature Review

2.1 Brief history:

Environmental Education (EE)

It is acknowledged that the primary antecedents of Environmental Education (EE) were Nature Study, Outdoor Education, and Conservation Education (Disinger, 1985). The term Environmental Education has been so vaguely defined over the years that it has been used synonymously with many different constructs: environmental-ecological education, ecological education, conservation education, camping education, outdoor education and environmental science education (Disinger, 1985). One of the most renowned experts on EE, Harold Hungerford, has concluded that EE is not synonymous with the previous fields, but that it has been defined and given substantive structure and boundaries (Hungerford, 1975). The definition that Hungerford (2005) uses, because of its easy and clarity, is from the Federal Register and states that:

> Environmental education is a process that leads to responsible individual and group actions… Environmental education should enhance critical thinking, problem solving, and effective decision-making skills. Environmental education should engage and motivate individuals as well as enable them to weigh various sides of an environmental issue to make informed and responsible decisions (US EPA, 1992, p.47516).

EE became a common phrase and topic of interest in the 1960's and 70's. This topic of interest quickly turned into efforts to compose a conceptual framework for EE, built on shaping attitudes, motivations and skills (Hart, 1981; Harvey, 1977a; Hungerford, Peyton, & Wilke, 1980; Stapp et al., 1969; UNESCO, 1977). In 1978 the world's first Intergovernmental Conference on Environmental Education, organized by UNESCO in cooperation with the United Nations Environment Programme (UNEP) was convened in Tbilisi, Georgia (USSR). At the close of the conference, the Tbilisi Declaration was adapted by acclamation. Within the document, among the goals and guiding principles of EE, were the five categories of objectives. The Tbilisi EE

categories, which provided a solid EE framework for almost two decades, included Awareness, Knowledge, Affect, Skills, and Participation (UNESCO, 1978).

> Awareness: to help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems.
>
> Knowledge: to help social groups and individuals gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems.
>
> Attitudes: to help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.
>
> Skills: to help social groups and individuals acquire the skills for identifying and solving environmental problems.
>
> Participation: to provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems (Hungerford, Bluhm, Volk & Ramsey, 2005 p. 15).

In his Ph.D. dissertation entitled *Environmental Education: A Delineation of Substantive Structure,* Gary Harvey (1977) constructed the generally accepted definition of EE, which has endured centuries of rigorous disassembling and evaluation. This is the definition most experts in the field refer to (Disinger, 1985). Hungerford also refers to and accepts this mediating definition as an alternate to the Federal Register's (Hungerford, Peyton & Wilke, 1983). After a thorough review of the literature, Harvey defined EE as:

> An interdisciplinary, integrated process concerned with resolution of values conflicts related to the man-environment relationship, through development of a citizenry with awareness and understanding of the environment, both natural and man-altered. Futher, this citizenry will be able and willing to apply enquiry skills, and implement decision-making, problem-solving, and action strategies toward achieving/maintaining homeostasis between quality of life and quality of environment (Harvey, 1977b, p. 158).

For the purpose of this research, Harvey's definition brings in an important concept of interdisciplinary processes, which is lacking in the U.S. EPA definition. This concept is foundational to the research assessment tool and is covered under Implications and Conclusion, section 5.

Environmental Literacy (EL)

The concept of Environmental Literacy (EL) has been evolving since it was developed, to advance the field of EE, in 1969 (Roth, 1992). The term gained great attention when President Richard Nixon began using it in his speeches for the National Environmental Education Act. In 1992 interpretive scientist Charles E. Roth, who first introduced EL to the world, presented the three major levels of EL: nominal EL, functional EL, and operational EL (Roth, 1992). Roth gave environmental literacy a purpose in society. For the first time, EL was seen as a continuum based on knowledge, values, beliefs and actions. Hungerford and Tomara (1977), considered an environmentally literate citizenry as both competent and willing to take action on critical issues. Roth (1992) also emphasized the need for knowledgeable citizens, who took action, who worked to solve human/environment issues such as population growth, nonrenewable resources, consumption, pollution and social injustice. EL became a common term used in schools and academic boards across the nation when the American Society for Testing and material (ASTM) developed consensus standards on EE with a clear definition for EL.

EE and EL took another great leap when Dr. Deborah Simmons developed a new framework for environmental literacy. This framework was based on seven common clusters of elements:

(1) Affect- environmental sensitivity, attitudes, values, motivation and moral reasoning

(2) Ecological Knowledge

(3) Socio-Political Knowledge- the relationship of cultural, political, economic, religious and other social factors influencing perceptions and activities

(4) Knowledge of Environmental Issues

(5) Skills- environmental problems/issues and action/service (analyze, investigate, evaluate)

(6) Determinants of Environmentally Responsible Behavior- locus of control/efficacy, and assumption of personal responsibility

(7) Behavior- various forms of active participation in solving problems and resolving issues (Simmons, 1995).

Since 1995, environmental literacy assessment instruments have been published (Wilke, 1995) as well as several national studies using assessments of environmental literacy (e.g., Erdogan, 2009; McBeth, 20010; Negev et al., 2008; Shin et al., 2005), however, many of these studies have been conducted on middle school students. Simmons (1995) framework is still influential today and has been used in proceeding research by Volk and McBeth, (1998), as well as by the National Guidelines for Excellence Project to develop guidelines for state standards. On December 1, 2011, NAAEE released *Developing a Framework for Assessing Environmental Literacy* at the National Press Club in Washington, DC, which although still needs some work, is the most promising national framework the country has seen in decades. In 1997 the Organization for Economic Co-operation and Development (OECD) started the Programme for International Student Assessment (PISA) (Hollweg et al., 2011). Over 70 countries have participated in the PISA surveys, which test reading, mathematical and scientific literacy in terms of general competencies. The age group of tested students is between 15 years 3 months and 16 years 2 months, an age right before many students in European countries end compulsory education. On August 28, 2011, PISA proposed a framework for assessing EL in 2015. This will be the largest international research project ever conducted in EL.

2.2 Definitions of Literacy

Individuals are either illiterate or literate, the difference separated by a threshold of reading and writing skills. Literacy has been further subdivided into four categories: conventional literacy, functional literacy, cultural literacy, and critical literacy (Tozer, Violas & Senese, 2006). Conventional literacy has been described as the absolute basics, the ability to read and write. There is no connection, however, to greater comprehension. An example of this would be a child's ability to recognize or write his or her own name, but decoding a single word is not necessarily the same as reading comprehension. This is considered the lowest level of literacy. The highest level of literacy is critical literacy, founded on critical though. This type of literacy is the ability to use a greater source of experiences and knowledge to compare and critique writings. This requires, not only knowledge of one's culture, but knowledge of many cultures' values, beliefs, views and opinions. The ability to give greater meaning to what is read holds great power in societies. Power implies control and those who are illiterate have the ability to control economic and political oppression. With critical literacy the readers are empowered and are able to escape these racial, ethnic, gender or social discriminations. (Tozer et al. 2006).

Literacy, therefore, plays a key role in the balance of power, which is why it is so highly valued in the United States, a nation built on democracy. Without first content and knowledge, how can individuals participate in critical thought, reading and writing on topics such as global climate change, ecosystem destruction or air quality? These are important issues we, as a society, are facing today. More attention has slowly been drawn to this topic, which influenced the birth and establishment of science literacy and environmental literacy.

2.3 Definitions of Science Literacy

In western culture there has been great emphasis placed on the importance of scientific literacy. Science and its technology have given us national security, medicine, clean water and air,

the ability to explore the universe and so much more. It is no wonder that we aspire to raise up a generation of scientifically literate individuals who understand a scientific method, can think critically about evidence based research and who feel prepared, knowledgeable and confident when facing scientific dilemmas.

> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (National Research Council, 1996, p. 22)

The above definition can stand the tests of time, however, it is sometimes more meaningful to use examples that individuals can put into present day context. For this reason, Hazen and Trefic's (1991) definition is also one of importance. They describe scientific literacy as the following.

> The knowledge you need to understand public issues. It is a mix of facts, vocabulary, concepts, history and philosophy. It is not the specialized stuff of the experts, but the more general, less precise knowledge used in political discourse. If you can understand the news of the day as it relates to science, if you can take articles with headlines about genetic engineering and the ozone hole and put them in a meaningful context… you are scientifically literate.

James Trefil (2008) would agree that this should be the goal of science literacy, not to make every person an expert scientist, but for an alternate goal, that every individual be able to read a newspaper the day they graduate from high school. Unfortunately, the science educational system does not have this as their aspiration and the number of citizens who are considered scientifically literate in the United States is low. It has only increased from 10 percent in 1988 to 28 percent in 2010 (Miller, 1989; Miller, 2011).

Scientifically literate individuals continually ask questions and seek answers. It is inevitable that one day they will ask questions about their environment and contemplate whether their actions are affecting the global balance of life. Questions of sustainability, earth and atmospheric systems, energy, natural resources, as well as human and environmental interactions fall under a more specific category. Those who use science to answer environmental questions and then alter their actions to echo the scientific demands for stability are considered not just scientifically literate, but also environmentally literacy.

2.4 Definitions of Environmental Literacy

Stephen Schneider (1997), from Stanford University, stated that the objective for an environmentally literate society is not the unattainable goal of detailed knowledge of content. He thought it absurd to require citizens be knowledgeable in all environmentally relevant disciplines. There is much truth in this statement. It is ridiculous to expect a layperson to obtain and utilize the knowledge of an expert. This does not mean that an environmentally literate citizen lacks the core concepts, methods and skills of environmental science. The values an individual holds and the action he or she takes is an outward display of understanding these core concepts.

Defining environmental literacy has proven difficult over the past 50 years. It is not only the ability to read and write about the environment, but an intimate connection with the environment that influences our actions and affect our conscious and subconscious behaviors.

Disinger and Roth (1992) describe environmental literacy as the ability to perceive and interpret the health of an environmental system and then to take actions to improve, restore or maintain those systems. They believe environmental literacy is reflected in observable behaviors and actions, not just the opinions of an individual.

An environmentally literate person knows that, as a consumer, they affect the environment. They acknowledge that his or her choices as a consumer either help or harm the

environment and that what they do as an individual or with their community can inhibit or aid the Earth in sustaining biological life (see, for example, Erickson 1997, Goleman 2009, McKibben 2007, Payne 2010). Richard Wilke and Harold Hungerford encouraged citizens to become environmentally knowledgeable and "above all, skilled and dedicated citizens who are willing to work individually and collectively for achieving and/or maintaining a dynamic equilibrium between quality of life and quality of the environment." (Wilke, 1996, p. 15) Those who are considered environmentally literate will make decisions as a consumer and involved citizen to keep ecosystems healthy. In return they will create a high quality of life for themselves and future generations.

Just as literacy is divided into four categories, environmental literacy can also be categorized along its continuum. Roth (1992) describes in his book, *Environmental literacy: Its roots, evolution and directions in the 1990s,* three degrees of environmental literacy. The first is Nominal environmental literacy, which is the lowest literacy of the three. It includes a rudimentary sensitivity for environmental issues, an acknowledgement of human environment interactions and a basic understanding of natural systems. The second is the Functional environmental literacy. This goes beyond the basic knowledge of human-environment interactions into an understanding of positive and negative affects. There is now a sense of concern for the environment based on the knowledge of human harm and destruction to the environment. An individual may even begin to develop new skills in which to analyze and assess information. They will begin to express desire for personal, as well as local or global, change and action. Operational environmental literacy is the highest environmental literacy. This is when a deep knowledge of ecological and environmental concepts bring about, not only understanding, but also are valued enough to impact their actions. This environmentally literate individual expresses a strong union between their values, beliefs and actions. They are constantly reading, writing and critiquing environmental literature and information. They have a strong connection with the environment and feel a

responsibility to ensure its protection and stability. Action is not only taken on a personal level, but they encourage action in their community and on a global scale.

The most contemporary definition of environmental literacy was released in the 2011 NAAEE document, *Developing a Framework for Assessing Environmental Literacy,* which stated,

> Environmental literacy is knowledge of environmental concepts and issues; the attitudinal dispositions, motivation, cognitive abilities, and skills, and the confidence and appropriate behaviors to apply such knowledge in order to make effective decisions in a range of environmental contexts. Individuals demonstrating degrees of environmental literacy are willing to act on goals that improve the well-being of other individuals, societies, and the global environment, and are able to participate in civic life (Hollweg et al., 2011).

Using this clear definition of environmental literacy as well as the Colorado Academic Standard's outline of critical concepts and skills students are expected to master in K-12 (see Table 2.1 in Appendix), environmental literacy can be measured and assessed. It is important to measure such academic knowledge because of its significant implications. Environmental literacy must be achieved to overcome current, and prevent future, environmental crises.

2.5 Current demand for EE and EL

Coyle (2005) has shown that only 1% or 2% of Americans are considered environmentally literate. Working with National Environmental Education & Training Foundation (NEETF) he created the Environmental Literacy in America assessment tool in 1997. The NEETF/Roper Survey of Environmental Knowledge was a test, with only a dozen questions, used to assess an average American adult's knowledge on topics such as watersheds, recycling, electricity and other environmentally relevant topics. The survey was given and results compiled from 1997-2005. The results show that only one third of American adults can pass the survey with a grade of A, B or C. However, 95% of American adults (96% of parents) think environmental education should be taught in schools, which indicates that although they do not themselves have the knowledge necessary to be environmentally literate they do see a need for it (Coyle 2005).

A total of 301 respondents completed a survey, the Colorado Alliance for Environmental Education and Colorado Environmental Literacy Plan (CAEE CELP), in thirty-three Colorado counties represented in Figure 2.1 (see Appendix). There were 60 respondents who identified as either a parent or a guardian of a child in K-12. When the parents were asked which topics they want teachers to cover in greater depth, the top responses, with 71.7% of the vote, were environmental systems, environment and economy, current environmental issues and personal and civic responsibility. When teachers were asked what the greatest barriers were to teaching EE in the class the top answer, with 22.1% of the vote, was that there is not enough time to incorporate EE. At the college level, over 22 staff, administrators and faculty from at least 7 universities or colleges responded to the survey from departments including: science, education, natural resources, environmental studies, museum studies, business and architecture. The survey showed that 23.5% implement EE in their classrooms every day, compared to only 5.9% of teachers K-12 ("Colorado environmental literacy," 2010).

Although many parents and teachers would like environmental education in the classroom, they are finding it difficult to implement because of State and National restraints. The No Child Left Behind Act of 2001 (NCLB) was an educational reform enacted to increase academic accountability nationally. This new law placed great emphasis on state-defined educational standards and benchmarks, with great importance placed on reading and math scores. A school that does not meet its state's "adequate yearly progress," (AYP) two years in a row, is considered "in need of improvement" (Tozer, 2006, p. 463). The AYP's have led to States firing teachers and closing schools. This places teachers in a difficult predicament. They are now forced to focus their instruction exclusively on topics covered in the state assessments. Many schools and teachers are obligated to abandon environmental education programs to invest more time and money in math and language arts. When time is spent on topics outside test-related instruction, this is considered discordant and precarious.

This system has been built on coercive power, one that instills fear in the educators that either something bad will happen to them or something good will be taken away from them if they do not comply. As with all coercive power, commitment is superficial and energies have quickly turned to sabotage and destruction (Covey, 1991). Educators are not satisfied with the current system and are waiting for a bright new solution, one that values their skills as educators and places less emphasis on standardized tests. In spite of the current situation, many states have decided to pursue frameworks for environmental literacy.

There is no shortage of prospective environmental literacy plans in the United States. Currently, 46 states are working on environmental literacy plans (ELP), four states have passed legislation for the creation of ELPs (DC, NJ, OR, CO) and two states that have completed their plans (MD, OR) (Navin, 2010). The No Child Left Inside (NCLI) Act is a piece of federal legislation that hopes to develop environmental education statewide. They aim at providing specialized development opportunities in environmental education. The legislation cannot move forward, however, unless there is an environmental literacy plan to access funds. In 2008 the NCLI was passed in the House with significant support. It was re-introduced into both the House and Senate in 2009 and is currently in committee ("NCLI," 2011). The environmental literacy plan that the NCLI is focusing on has been created by the Colorado Alliance for Environmental Education (CAEE). There are 6 major requirements for these environmental literacy plans that the CAEE has outlined:

1. State content standards and how they relate to environmental literacy
2. Programs for the professional development of teachers
3. How the state will measure the environmental literacy of students
4. The relationship of the Plan to state graduation requirements
5. How the Plan will be implemented

6. Peer review of the Plan by major stakeholders, including State and federal agencies, non-profits, and other groups (CAEE, 2011).

This research focuses primarily on the first of these six requirements, state content standards and how they relate to environmental literacy. This research does, however, have implications for numbers two and three as well.

Rather than restrict measurement to the standardized tests or assessments as NCLB did, a combination of approaches can be used to measure students' EL. Until Colorado has completed their ELP, we must rely on existing content standards to implement EE into the curriculum. The Department of Education has incorporated human environment interaction and ecological knowledge into the content areas of science and social studies. This research merely assesses one part of EL, basic environmental science knowledge acquisition, which is most accurately measured using a multiple-choice survey. The full measure of EL includes more than just content knowledge. It is not suggested that multiple-choice assessments be used to measure the other areas under examination in environmental literacy, such as attitude. This latent construct must be inferred from overt responses rather than measured directly (Milfont, 2010).

2.6 Measuring EL with State Standards

Academic standards were created to ensure that all school students would receive a high quality and consistent public education. Although the government does have great influence, education is not completely nationalized or global. In fact, each state in the US has its own process for developing, adopting, and implementing standards. The standards based education measures each individual student against a set of standards, as opposed to norm referenced education measures that evaluate students against their peers. This system emphasizes the use of criterion-referenced assessments. These educational assessments were created to make an official valuation

of academic attitudes, skills and knowledge in a specific content area. For this research, the content area of interest is science.

State agencies do not currently measure the environmental literacy of students. Colorado K-12 content standards for science include Physical Science, Life Science and Earth Systems Science. The purpose of the science standards is to ensure the readiness of our students when released into a world that embodies 21st century skills and technology. It is vital our K-12 educational system encourages skills in research and technology, as well as a sense of care for, not only humans, but for the flora and fauna which surround them. The members of the Colorado Department of Education (CDE), who compiled the standards, have emphasized that more than anything their desire is to give Colorado students the ability to continually interpret evidence. Especially in this day and age when, "pseudo-scientific ideas and outright fraud are becoming more common place. Developing the skepticism and critical thinking skills of science gives students vital skills needed to make informed decisions about their health, the environment, and other scientific issues facing society" ("Colorado academic standards," 2009, p. 7). The CDE want to provide students with the tools necessary to decipher true science from pseudoscience. Science is often separated from value-laden politics, ethics and economics, however, in order to cease the destruction of the planet, there must be an intersection to promote personal responsibility. This intersection cannot affect the logic, methods, rationality or results of science, but rather affect the actions we take in response to its enlightenment.

Some of the most pertinent issues our children will (unquestionably) face are those of the environment. Climate, water and air pollution, ecology, biodiversity, sustainable agriculture, toxic waste management, limited natural resources, sustainable economic development, these are the core issues that, not only our future scientists, but also future citizens will face. It is important that individuals are able to articulate their environmental concerns, ideologies and critical rhetoric. With these issues in mind, the Department of Education began their revision of the existing

Colorado Standards, Colorado Student Assessment Program (CSAP) tests, which have been in use the past fourteen years. During the transition into the new standards, Colorado school districts will be using what are called the Transitional Colorado Assessment Program (TCAP) though 2013 until the old standards are completely phased out. By 2014 school districts in Colorado should have completed implementing the new tests ("CSAP / TCAP," 2011).

The new Science Standards were divided into three sections based on topical organization. The three standards of science are:

1. Physical Science- Students know and understand common properties, forms, and changes in matter and energy.
2. Life Science- Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.
3. Earth Systems Science- Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space ("Colorado academic standards," 2009).

Each standard is broken down by high school and grade level expectations, and these are further broken down into concepts and skills students should master. There has recently been a push to either add a fourth standard, an environmental science standard, or to encourage more environmental education within traditional subjects, such as science and social studies. Adding a fourth standard is not necessarily the best option for Colorado because of K-12 time restraints in the classroom. The department of Education has found that it is a better option to integrate EE into current classroom instruction. Using these new standards, imbedded with environmental concepts, students' environmental knowledge can be evaluated using an instrument that combines assessment from the American Association for the Advancement of Science as well as contexts from PISA's globally accepted environmental literacy framework (Project 2061, 1993; Hollweg et al., 2011).

3. Methods

3.1 Introduction to assessment

When students graduate from high school and continue along their path into adulthood, it is important that they have been given every tool necessary to move forward into college or career. It is also vital that they become a knowledgeable, positive and participating member of society. It is the responsibility of the Department of Education, teachers, parents and society to grow environmentally literate individuals. Currently, there are not any state assessments testing environmental literacy that are directly related to state academic science standards (see Table 3.1 in Appendix). At the college and university level of education it is difficult to quantify each student's understanding of the concepts learned under the Colorado science standards.

The Introduction to Environmental Science Course at the University of Colorado Denver (UCD) is filled with students from diverse backgrounds. Each semester there are roughly 200 non-science majors who sit through the course. They do not necessarily enter the course because they are interested in Environmental Science. UCD requires that all graduating students take at least one course with a lab. Many students pick Intro to Environmental Science because it fulfills this requirement. (see Figure 3.2 in Appendix)

What this means to the professor teaching the course is that there are students from many different disciplines signing up for the class. Since it is an introductory course, the only prerequisite is the completion of the Science Standards in K-12. It is important that key concepts learned in High School, Middle School and even Grade School are carried through to the undergraduate level. Although students come from all across the state, country and even world to attend UCD, 70% of students who sign up for this introductory course have attended K-12 in Colorado. These students should, theoretically, understand key concepts in Environmental Science (ES) and be able to pass an assessment of their environmental knowledge. Although ES

has only recently been incorporated into the standards, this does not imply that older students are any less environmentally literate than their younger peers. Environmental knowledge can come from sources outside of education, such as family, media, peers and personal experience. The purpose of this assessment instrument, *Assessing the Environmental Literacy of Intro Environmental Science Students* (AELIESS), is to gather information about a diverse group of students' environmental knowledge (see Figure 3.3 in Appendix). A quality learning experience is designed with the students in mind. Student-centered course design takes into account the students' knowledge, learning styles and needs. Instead of simply transmitting a body of environmental knowledge to the students, the educator uses active learning such as critical thinking and problem solving. With the use of AELIESS, the educator limits the assumptions he or she makes about the students' environmental knowledge and literacy. AELIESS gives educators some baseline data, a starting point from which the course curriculum can be built. It also gives freedom from repetition of concepts if students are already knowledgeable in certain areas. Most importantly, it aids in the ultimate goal of the course: moving students from a nominal to an operational environmental literacy.

3.2 Creation of AELIESS

When creating the new science standards, the Colorado Department of Education committee used a variety of resources, including: Science for all Americans (Rutherford, 1990), Benchmarks for Science Literacy (Project 2061, 1993), and The Atlas for Science Literacy (AAAS, 2001a). By relying on the Colorado Department of Education as a resource to create the AELIESS instrument there is less subjectivity and higher validity concerning the content of items. Eight of the 16 multiple-choice questions were taken directly from the American Association for the Advancement of Science (AAAS) website. Each of the AAAS questions was chosen from key ideas within the science standards concepts. The AAAS Science Assessment was established

under Project 2061 and a website was created for public access. For each science topic, including Physical Science, Earth Science, Life Science and the Nature of Science, the website has a list of sub-ideas, a list of items, results from field testing, and a list of student misconceptions for each individual question. The other eight, non-AAAS, questions on the instrument were created using the new Science Standards as guidance, as well as the PISA Framework for Environmental Literacy (Hollweg et al., 2011). Although the questions were chosen from three different topics, or subdomains, the questions for the instrument all had an overarching environmental theme unifying them. Each question further identified with one or more specific 'contexts' in environmental science. These contexts included biodiversity, natural resources, environmental quality and health, natural hazards and extreme weather, and land use (see Table 3.4 in Appendix). The PISA Environmental Literacy Framework provided examples of each context, all of which (except population growth) were used in the development of test items on AELIESS (Hollweg et al., 2011, p.20). Population growth is considered a topic in the social studies standards; therefore the context was excluded from the assessment. Over 37% of AELIESS items included biodiversity, nearly 44% included natural resources, 25% included environmental quality and health, nearly 19% included natural hazards and extreme health and 12.5% included land use (see Table 3.3 in Appendix).

3.3 Identification of measure

A. General Information

The instrument is titled, *Assessing the Environmental Literacy of Intro Environmental Science Students (AELIESS)*. It has the ability to highlight topics and concepts a majority of the students may be struggling with. Areas the students have mastered can also be identified. By highlighting these problem areas the instructor can make the most of their time with the students and can focus on their actual needs, as apposed to their theoretical needs. This assessment

instrument could potentially be used by any introductory course in environmental science, however, the questions are based on Colorado Standards, thus this assessment is most effective when given to students who have attended, at least, grades 9-12 in Colorado.

1. Purpose(s) of measure

Assess environmental literacy among students in Intro to Environmental Science. The assessment could potentially be given to K-12 students, post-secondary students, pre- and in-service teachers, or the general public. The purpose of the assessment is not to be used as an exit exam for high school graduates, although it could accurately measure their knowledge in environmental science. It is not my intention to create yet another obstacle standing between high school students and their future goals. Standardized exams are many times the unscrupulous gatekeeper of occupational and educational opportunity. The instrument, for this research purpose, is to be used by instructors or professors in higher education to assess the environmental literacy of their students. With this information they may quickly discover which topics h/she should spend the most time reviewing or building upon throughout the semester. The instrument is an excellent indicator of the students knowledge, however, more research needs to be done to make the connection between what students know, how they feel, and how they act. It is important to keep in mind that a student could score a 100% on the assessment and still make poor environmental decisions in their every day life. Qualitative research is encouraged to bridge the gap for complete environmental literacy assessment.

2. Specific sub-domains assessed

The instrument has an over arching theme examining the students understanding of core concepts in environmental science. The more questions an individual is able to answer correctly positively correlates to the individual’s environmental literacy. Questions were chosen from content covered under sixth grade, eighth grade and high school standards, as lower grades’ concepts were simplified versions of the higher grade levels. There are three different content

areas under the standards: Physical Science, Life Science and Earth Systems Science. Each content area is further divided into concepts and skills the students should master. (see Table 2.1 in Appendix) The following represents the content areas and their concepts, which were used to create the AELIESS. Questions were selected based on their correlation to environmental concepts. Sixteen questions were created for the instrument for quantitative analysis.

B. Intended test population

1. Age

The Instrument can be given to anyone age 19 or older, unless the individual graduated early from high school and is enrolled in a college level course, this is the exception.

2. Specia1 groups

The instrument was not created for nor tested using individuals with disabilities or behavioral problems.

C. Administration

The instrument can be administered in individual or group settings. It is suggested that it is administered in a quiet room without distractions to maximize reliability. It is also suggested that the assessment is given the first day of class if given in a classroom setting.

D. Time required

The actual testing time is approximately 20 minutes. Total administration time is approximately 30 minutes, 5-10 of which is spent establishing rapport and giving oral instructions to the students. Any questions the students might have are answered before passing out the instrument.

E. Stimulus items

The respondent is given a form on which they fill out the demographic information, including their gender, age and ethnicity. The respondent is then asked if he or she graduated High School and must circle either yes or no. They are also asked how many years of K-12 they

attended in Colorado. Then the instructions ask them to read and complete 16 multiple-choice answers by circling one answer. Only one question, under the life science questions, has pictorial representation (a flow chart) to aid in completing the question. The 16 questions are used to quantify the respondent's understanding of basic environmental systems and concepts. This portion is all that is necessary to assess the students' knowledge of environmental literacy.

The assessment could be given with a scantron so that the hard copies could be reused, saving time and resources.

F. Administration Procedures

After obtaining approval for human subjects research by the International Review Board, the instrument can be administered and scored by individuals without formal training in assessment. The instrument was created for Colorado educators in the Environmental Sciences, specifically at the College and University level. There are not multiple tests or sections thus there is not a specific sequence of actions for administering the measure. The first official administration of AEILESS was conducted in the Spring 2012, before classes had begun. In the future, a second assessment could be created assessing the respondent's actions, values and behaviors, in which case, the two instruments should be taken simultaneously and then scored to assess overall disposition towards the environment, as well as gaps between attitude and behavior.

G. Scoring Procedures

Interpretation of the instrument's scores requires graduate training in environmental science or related fields. To score the assessment, the numbers of correct answers are tallied, giving a raw score for each individual student, which are then compiled and averaged. This gives an idea of the overall performance of the class. The second step in scoring the assessment is to sum up the individuals' correct answers for each sub-domain (Physical Science, Life Science and Earth Systems Science), and then these are compiled and averaged. This gives an idea of the overall performance of the class within each sub-domain. By looking at the averages, medians and

modes within each domain, areas of difficulty can be identified. For this type of continuous scale, zero to 16, the measure of central tendency that is the most meaningful is the mean. Scoring of the multiple-choice section of the instrument could be done quickly and easily using scantrons. This is the most efficient way to score large groups of students efficiently and with as little human error as possible.

H. Interpretation procedures

Demographic information should be analyzed for trends and changes in the student population over time (for example, the average age of a population may increase or decrease from one semester to another, which could correlate to overall performance). Trends should also be analyzed for ethnicity. Total mean score for the population as well as for each of the sub domains (Physical Science, Life Science, Earth Systems Science) should be calculated and analyzed to reveal an overall level of understanding environmental concepts as well as reveal which, if any, of the three sub domains the students are struggling with.

3.4 Support for measure

A. Item selection

Each item on the assessment was put through a pilot test before the final instrument was completed. This 16-item MC question form was collected from students in two Environmental Science sections at UCD in the fall semester of 2011. There were not any individuals who identified themselves as having any special education needs. First, the statistical properties of individual items were examined in the combined sample. Items for which responses were frequently missing (i.e. Suggesting that such items were poorly worded, or frequently misunderstood) were eliminated. Using SPSS, each item score was correlated with the total score within each scale, and then items with the lowest item-total correlations were modified. Principal Component analysis was used as a second approach for clarifying scale structure and determining

the strength of scale membership for each item. Each of the analyses identified three predominant factors and one or two secondary factors that accounted for the majority of variance within a scale. These latter factors contained only a few items and accounted for minimal variance.

B. Validity evidence

Validity was based on the content of its items (content validity) and the internal structure of the instrument (discriminant validity) and whether the operationalizations of the construct actually measure Environmental Science and literacy (construct validity). Using excel, item analysis was conducted to determine internal consistency. This included assessing the difficultly of each AELIESS item, as well as the relationship between how well students did on the item and their total score. The item difficulty index ranges from 0 to 1, the higher the value the easier the question. If the item difficulty is 0.79, this means that 79% of the students answered the question correctly. The ideal difficulty for a four-response multiple-choice question is a moderate score of 62%. Difficulty is measured on a scale classifying 85% or above as easy, 51 to 84% as moderate and 50% or below as hard. Comparing students' item responses to their total test scores assesses the quality of individual items. This test should discriminate between students who are environmentally knowledgeable and those who are not. The item has low discrimination if it is too difficult or too easy. Item discrimination, also called Point-Biserial correlation (PBS), is considered good if it is above 0.30, fair if it is between 0.10 and 0.30 and poor if below 0.10.

Construct validity was examined using Principal Component Analysis (PCA). Loadings in excess of .71 (50% overlapping variance) are considered excellent, 0.63 (40%) is very good, 0.55 (30%) good and 0.45 (20%) fair, and 0.32 (10%) is considered poor. The items are expected to load primarily on one overarching component, Environmental Science, or on three components, Physical Science, Life Science and Earth Systems Science. The eigenvalues over one should account for most of the variance.

C. Reliability

Internal consistency estimates the reliability of test scores using Cronbach's alpha. The scale, from 0 to 1, indicates the degree to which the set of items measure a single unidimensional latent construct. The construct for this research, unifying the items is Environmental Science. Higher values of alpha indicate higher intercorrelations among test items and thus increased reliability. A Cronbach's $\alpha \geq .9$ is considered to have excellent internal consistency. Good internal consistency is $.9 > \alpha \geq .8$, acceptable is $.8 > \alpha \geq .7$, questionable is $.7 > \alpha \geq .6$, poor is $.6 > \alpha \geq .5$, and unacceptable is $.5 > \alpha$. Running Cronbach's alpha on SPSS gives the Item-Total Statistics, which includes Cronbach's Alpha if an item is deleted. This gives the option of removing an item to significantly raise the internal consistency.

4 Results and Discussion

Figure 4.1 Difficulty and Discrimination Distributions, illustrates the correlation of each AELIESS multiple-choice item to the total score (0=no correlation, 1=perfect correlation) as well as the difficulty of the items (0= most difficult, 1= least difficult).

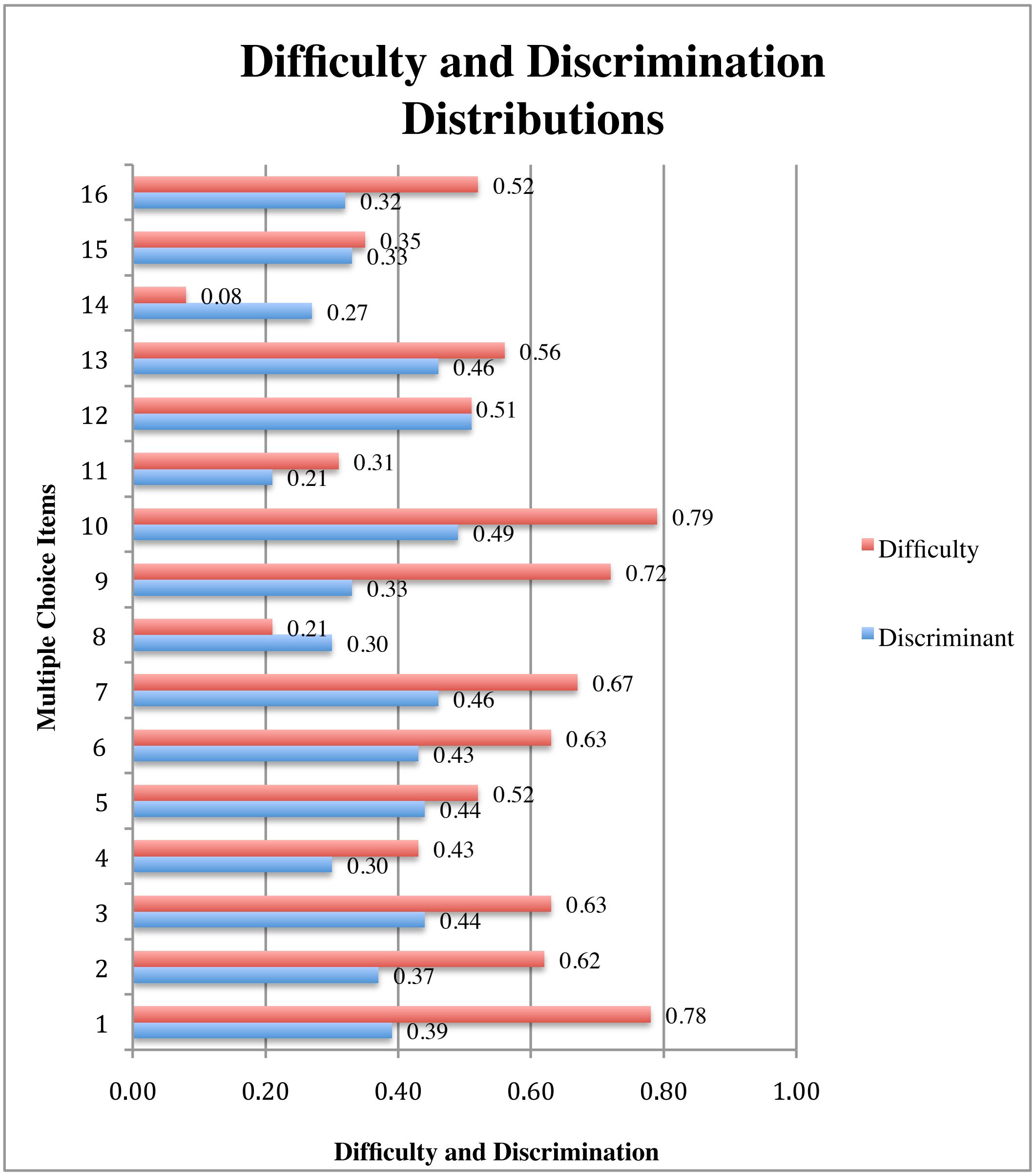

Figure 4.1, Difficulty and Discrimination Distributions, illustrates the difficulty of each item as well as its correlation to the overall score. All of the items, except numbers 14 (Earth Systems Science) and 11 (Life Science), were above 0.30 for difficulty. In order of decreasing difficultly, the items are: 14, 8, 11, 15, 4, 12, 5, 16, 13, 2, 3, 6, 7, 9, 1 and 10. Item number 14 was the most difficult with only eleven individuals out of 144 (8%) answering correctly. This item was the most difficult for students in the pilot test as well. After changing the wording, the difficultly was expected to decrease, but did not. The PBS for number 14 is 0.27, which is at the higher end of fair, indicating the eleven students who did answer this item correctly scored highly overall. There were only nine Environmental Science majors in the class and of these, four answered number 14 correctly. The fact that students did poorly on this question does indicate that students are either not familiar with balances between energy production and environmental impact, or they are not familiar with the newest forms of renewable energy. Many students are familiar with solar energy, which is why it was the number one incorrect response from all participants. It is important to identify common misconceptions so that they can be addressed. This is why the item was not removed from the test after the pilot study.

The PBS also revealed that all of the correlations were above 0.20, which indicates high discriminant validity. Students who showed the highest comprehension of the concepts scored the highest overall, and got the most difficult items correct, whereas students who had lower test scores got the difficult items incorrect. Correlations of 0.40 or higher, showing the highest validity on the exam, were numbers 12, 10, 7, 13, 3, 5 and 6, which were primarily from the Life Science sub-domain.

Table 4.1 Total Variance Explained: displays eigenvalue loading on three items explaining 33.73% variance as well as the seven components, loading higher than one, explaining 61% variance.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.388	14.925	14.925	2.388	14.925	14.925
2	1.563	9.771	24.696	1.563	9.771	24.696
3	1.445	9.032	33.728	1.445	9.032	33.728
4	1.240	7.752	41.480			
5	1.058	6.612	48.092			
6	1.038	6.486	54.578			
7	1.007	6.293	60.871			
8	.945	5.908	66.779			
9	.895	5.595	72.374			
10	.827	5.166	77.540			
11	.731	4.569	82.109			
12	.694	4.337	86.446			
13	.644	4.024	90.470			
14	.551	3.447	93.917			
15	.508	3.173	97.090			
16	.466	2.910	100.000			
Extraction Method: Principal Component Analysis.						

Table 4.2 Principal Component Analysis: displays loading on three primary components. Loading occurred primarily on the first component.

Component Matrix[a]			
	Component		
	1	2	3
1	.387	-.434	.175
2	.315	.018	.255
3	.505	.050	-.396
4	.249	.139	-.558
5	.390	.235	-.325
6	.482	.174	.028
7	.478	-.027	.056
8	.188	.515	.160
9	.396	-.326	-.146
10	.582	-.372	-.086
11	.093	-.182	.531
12	.450	.422	.311
13	.607	-.129	-.014
14	.008	.596	-.129
15	.160	.408	.182
16	.272	.085	.538
Extraction Method: Principal Component Analysis.			
a. 3 components extracted.			
Primary loading			
Secondary loading			

Using Principle Component Analysis (PCA) on the results, seven eigenvalues were identified larger than 1, accounting for 61% of the variance. The items could have loaded according to their contexts (see Table 3.3), however, the greatest loading were on three principle

components Identified as Physical Science, Life Science and Earth Systems Science (see Tables 4.1 and 4.2). There were meaningful correlations, of .32 or larger, between the items and the components they loaded on. The greater the loading, the more that variable is a pure measure of the factor.

There was not loading greater than 0.61 on any one component. A majority of the questions loaded on component one. High loading on only one component was expected, with a unifying theme of Environmental Science. If the questions had loaded atypically, this would suggest that the questions selected for the study were not environmentally founded. Factor analysis was also used to identify the difficultly of each item on the instrument, and also to compare how well the students' performance on an item correlated to their overall score. This provided greater clarity when attempting to interpret the factors and understand the underlying dimension that unified the groups of variables loading on it.

Cronbach's Alpha (Tables 4.3-4.5)

Table 4.3 Case processing summary: presents sample size and the percent valid and excluded cases.

		N	%
Cases	Valid	144	88.3
	Excluded[a]	19	11.7
	Total	163	100.0
a. Listwise deletion based on all variables in the procedure.			

Table 4.4 Reliability: which is a measure of the assessment's precision in scoring environmental science.

Cronbach's Alpha	N of Items
.602	16

Table 4.5 Item-Total Statistics: includes descriptives for each item, including which items should be deleted to increase internal consistency.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
1	7.566434	7.029	.253	.196	.582
2	7.727273	6.968	.215	.154	.588
3	7.720280	6.803	.284	.227	.576
4	7.916084	7.182	.122	.175	.604
5	7.825175	6.788	.275	.216	.577
6	7.720280	6.817	.278	.201	.577
7	7.678322	6.778	.308	.188	.572
8	8.139860	7.225	.165	.105	.595
9	7.629371	7.114	.182	.086	.593
10	7.559441	6.806	.367	.282	.565
11	8.034965	7.432	.041	.117	.615
12	7.839161	6.583	.358	.238	.562
13	7.790210	6.711	.309	.197	.571
14	8.272727	7.429	.173	.116	.594
15	8.000000	7.133	.154	.125	.598
16	7.825175	7.109	.148	.142	.600

The tables above (Tables 4.3-4.5) include the Case Processing Summary, Reliability and Item-Total Statistics for Cronbach's alpha. The alpha value for the AELIESS assessment, using all 16 multiple-choice items, was .602 (Table 4.4). Higher internal consistency could be achieved if additional items were added to the sub-domains, Physical Science and Earth Systems Science, which only contained three questions each. Table 4.5 reveals how Cronbach's alpha would be affected if an item were deleted. As you can see, deleting any of the 16 items would not greatly improve the reliability.

Table 4.6 Demographic information including percents of represented ethnicities.

Caucation	Hispanic	Asian	African American	Middle Eastern	Other	Non-response
50%	12.5%	4.86%	4.17%	3.47%	11.11%	13.89%

The sample size included 70 males, 59 females and 15 without a response resulting in a total sample size of 144, a mode age of 19 and a mean age of 22. Half of the population identified as having Caucasian ethnicity, whilst half of the population identified as either Hispanic, Asian, African American, African, Middle Eastern, Italian, German, Australian, Korean, Native American, Other or did not respond to the question at all. This was considered an ethnically diverse sample, with many different ethnicities, however, because sample sizes were small for ethnicities other than Caucasian, this inhibited examining the students scores with a t-test or ANOVA (as many ethnic groups had less than 3 members). Several t-tests and an ANOVA were run to determine if other demographic data (gender, age, K-12 attendance, high school graduate) affected how well individuals performed on the environmental assessment.

Table 4.7 Independent t-test between men and women's scores

	Levene's Test for Equality of Variances		t-test for Equality of Means					
							95% Confidence Interval	
	F	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1.123	0.291	1.167	0.245	0.56	0.48	-0.389	1.509
Equal variances not assumed			1.177	0.241	0.56	0.476	-0.382	1.502

Table 4.8 Group statistics for men and women.

	Male=1	N	Mean	Std. Deviation	Std. Error Mean
Sum	1	70	8.81	2.83	0.338
	0	59	8.26	2.57	0.335

A t-test was run to see if there was a difference in scores between men and women. A p-value of 0.245 > 0.05 indicates that there is not a significant difference in scores (see Table 4.7). Sample sizes were very close for the two populations, as well as the mean scores, which for men was 8.81 and for women 8.257 (Table 4.8). This indicates that individuals environmental literacy is low, regardless of gender. If there had been more than two groups (men and women) for the factor (gender) an ANOVA could have revealed differences in scores within and between the sub-domains.

Table 4.9 Independent t-test between high school graduates and non-graduates.

	Levene's Test for Equality of Variances		t-test for Equality of Means					
							95% Confidence Interval	
	F	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	0.588	0.445	-0.476	0.635	-0.9	1.892	-4.647	2.847
Equal variances not assumed			-0.592	0.656	-0.9	1.519	-18.055	16.255

Table 4.10 Group statistics for high school graduates and non-graduates.

	Graduate=1	N	Mean	Std. Deviation	Std. Error Mean
sum	1	120	8.6	2.658	0.243
	0	2	9.5	2.121	1.5

Another question was whether those who graduated from high school had a better grasp of environmental concepts. Table 4.9 shows a p-value of 0.635 > 0.05, which indicates that there is not a significant difference in scores. Both groups of students have similar environmental knowledge, although Table 4.10 shows that the mean score for those who did not graduate high school was 9.5 and for graduates was only 8.6. The sample size for the non-graduates was only two individuals, vs. 120 in the graduates' population. These two students could have received their GED's or could have been home schooled. Given a larger sample size with a larger population of non-graduates, this statistic could significantly change.

Table 4.11 Independent t-test for K-12 Colorado between those who attended Kindergarten through 12th grade in Colorado and those who did not.

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval Lower	Upper
Equal variances assumed	0.125	0.724	-0.203	0.839	-0.104	0.513	-1.118	0.91
Equal variances not assumed			-0.207	0.836	-0.104	0.503	-1.105	0.897

Table 4.12 Group statistics for K-12 Colorado and non-Colorado attendees

	K-12 yes=1	N	Mean	Std. Deviation	Std. Error Mean
sum	1	90	8.51	2.712	.286
	0	39	8.62	2.581	.413

The most surprising of the independent t-tests was between those who attended Kindergarten through 12th grade in Colorado and those who did not. The AELIESS assessment was specific to Colorado environmental knowledge in terms of the Colorado content standards that were used to construct the questions as well as the nature/specificity of the questions themselves. For example, item 13 specifically addresses available, renewable energy in Colorado. One could assume that those who attended school in Colorado would perform better on the question. Table 4.11 reveals a p-value of 0.839> 0.05, indicating that there is not a significant difference in scores between those who attended Kindergarten through 12th grade in Colorado and those who did not. The sample size was 90 for Colorado attendees and 39 for non-Colorado K-12 attendees, and the mean scores were 8.51 compared to 8.62 (see Table 4.12). Had the assessment contained more Colorado specific questions, the statistical difference could have been significant. Question 13 was considered one of the best questions on the assessment, with high internal validity (see Figure

4.1). An important aspect of environmental literacy is that students are aware of, not just global, but local means for solving environmental problems and achieving change.

Table 4.13 Descriptives on a One-factor ANOVA for Age and Average scores.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
18	11	6.82	1.601	.483	5.74	7.89	4	10
19	27	8.37	2.817	.542	7.26	9.48	4	15
20	23	7.91	2.539	.529	6.82	9.01	3	12
21	20	7.70	3.729	.834	5.95	9.45	0	14
22	16	8.81	2.228	.557	7.63	10.00	5	13
23	11	7.91	2.256	.680	6.39	9.42	4	11
24	6	8.83	2.927	1.195	5.76	11.90	4	12
25	3	8.33	2.082	1.202	3.16	13.50	6	10
26	4	9.25	1.258	.629	7.25	11.25	8	11
27	3	11.67	2.517	1.453	5.42	17.92	9	14
28	6	9.33	1.966	.803	7.27	11.40	6	11
29	2	13.00	.000	.000	13.00	13.00	13	13
30	2	8.50	4.950	3.500	-35.97	52.97	5	12
31	1	10.00	.	.	.	.	10	10
32	1	6.00	.	.	.	.	6	6
33	1	10.00	.	.	.	.	10	10
34	1	13.00	.	.	.	.	13	13
39	2	11.00	2.828	2.000	-14.41	36.41	9	13
Total	140	8.39	2.763	.234	7.93	8.85	0	15

Table 4.14 One-way ANOVA for Age and Average scores.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	177.338	17	10.432	1.440	.130
Within Groups	884.055	122	7.246		
Total	1061.393	139			

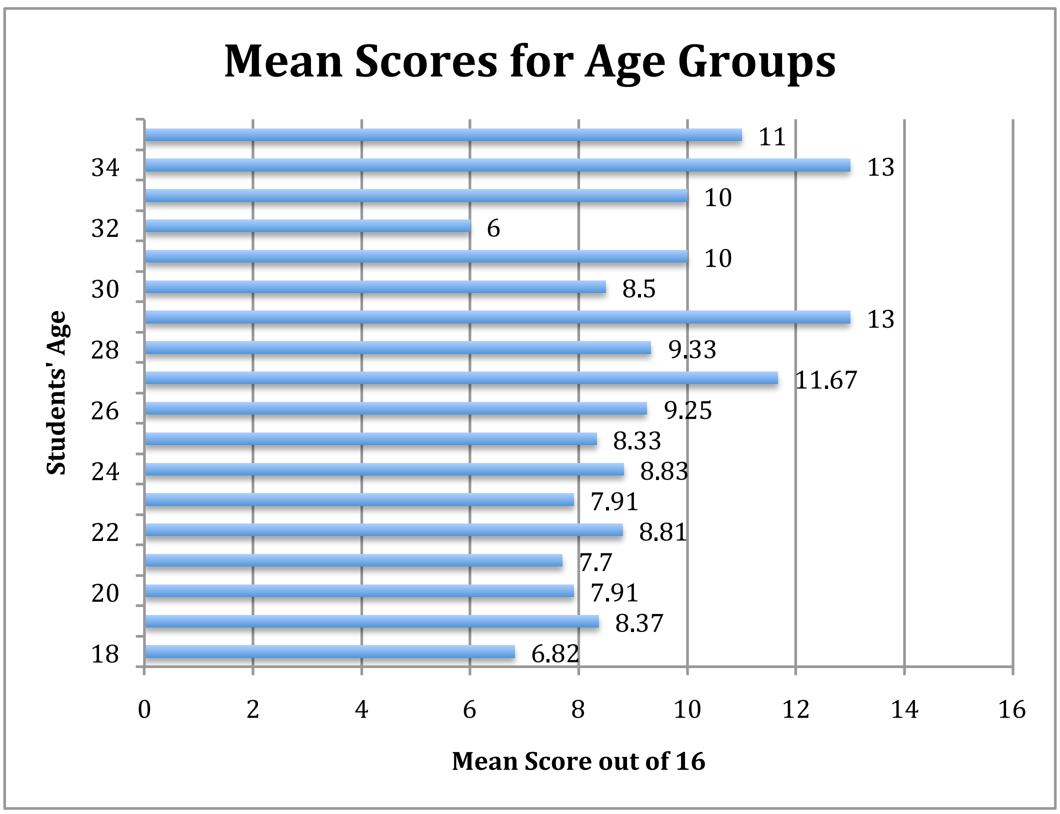

Figure 4.2 Graphical representations of mean scores for multiple-choice questions (1-16) for each age group (18-34 and 39).

Table 4.13 provides descriptives on a one-factor ANOVA for Age. The ages range from 18 to 39. The mean and range of scores for each age group are given, as well as the sample size of

each group. It is interesting to note that the age group ‘21’ had the highest score of 14, as well as the lowest score of zero. Table 4.14 gives a p-value of 0.130 > 0.05, indicating that there is not a significant difference between age groups and average score. Significance within groups could not be tested because some age groups had less than 2 individuals representing that group. For graphic representation of mean scores for age groups, see Figure 4.2. Visually, it appears that older students tend to have higher mean scores. This pattern is supported by data analysis in Table 4.15. Although every group from 18-25 contained at least one individual who scored ≤ 6, you can see that the individual 32 years of age scored a 6, graphically making that age group appear the most environmentally illiterate group. Figure 4.2 could be misleading, which is why it must be examined alongside Table 4.13.

Table 4.15 Independent t-test between individuals 18 to 20 years old and those 21 to 39 years olds, reveals a significant difference, p-value 0.006 < 0.05.

	Levene's Test for Equality of Variances		t-test for Equality of Means					
							95% Confidence Interval	
	F	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal var. assumed	1.645	0.202	2.766	0.006	-6.937	0.459	-2.176	-3.62
Equal var. not assumed			2.834	0.005	-1.269	0.448	-2.155	-0.383

Table 4.15 and Figure 4.2 both seemed to indicate a slight increase in score with age. To test this trend, the sample size was split, with one group representing 18 to 20 years of age and the other group 21 to 39 years of age. Table 4.15 Independent t-test between individuals 18 to 20 years old and those 21 to 39 years old, shows a p-value 0.006 < 0.05, indicating a significant difference in scores between the two groups.

Table 4.16 Group statistics for ages 18 to 21 and 21-39.

	Under 21=1	N	Mean	Std. Deviation	Std. Error Mean
Sum	1	81	7.86	2.867	0.319
	0	60	9.13	2.439	0.315

The mean score for those under 21 was 7.86 and for those 21 and older 9.13 (see Table 4.16). It is not clear why individuals in the older group would perform significantly better than their younger peers. One plausible explanation is that these students have taken more college level courses, any of which could have been related to environmental science. It could also be that they are "academically-savvy" and likely to look outside of academia for environmental knowledge and education, an idea discussed further on in the reading.

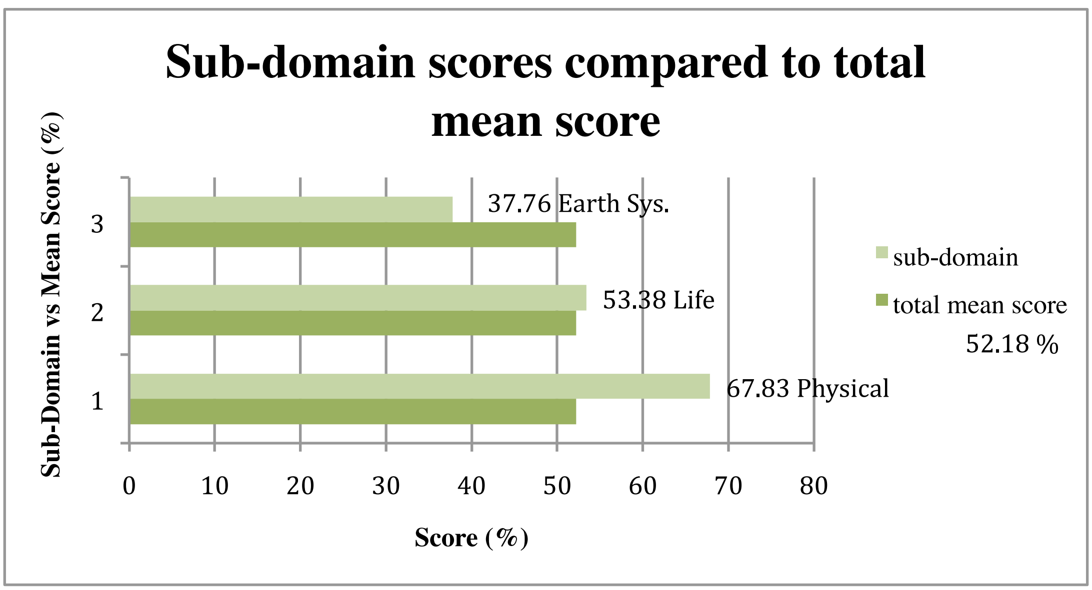

Figure 4.3 A comparison of the participants mean scores in the three sub-domains to the total mean score.

Figure 4.3 illustrates an overall performance of the population by comparing the sub-domain scores to the total mean score. The total mean score for the class was 52.18%, which

shows that the class as a whole does not have a strong foundation in environmental science nor high levels of environmental literacy and need further assistance in one or more of the three sub domains. Statistical analysis showed that on average the students scored a 67.8% in Physical Science, 53.4% in Life Science, and 37.8% in Earth Systems Science. The obvious area of concern for this population of Intro Environmental Science students is in Earth Systems Science. If we view figure 4.3 alongside Figure 4.1 and Table 3.3 (in Appendix), a few observations can be made. The most difficult questions for the students came from Life Science, items 8 and 11, as well as from Earth Systems Science, items 14 and 15 (see Figure 4.1). In Table 3.3, Distributions of contexts, these items fall most heavily under biodiversity and environmental quality and health. These are topics the instructor should allocate greater time for review.

The assessment could show that the students have a firm grasp on the foundational concepts learned in high school. In this case, the structure of Intro to Envs course could incorporate a more qualitative structure, increasing the students' connection with the environment through reading and research on topics of interest, weekly field exercises and research papers in oral and written form. The poor results illustrated in Figure 4.3 were not surprising. There has been an obvious lack of emphasis placed on environmental knowledge in the world of academia. Until recently, educators and policy makers have not seen the need for developing an environmentally literate youth. Transitioning environmental science into K-12 standards will be difficult for many educators. There is global concern as to whether teachers have the necessary basic knowledge of environmental concepts to teach students (Loubser, 2001). This could be why students in this sample have performed so poorly on AELIESS. The use of AELIESS could, therefore, be extended to K-12 teachers, to highlight gaps in their knowledge. It should not be used to reprimand or punish teachers. After all, it is not the educators' fault they were not required to take an environmental science course before receiving licensure. The main use of the assessment is to provide post-secondary educators and teacher development programs with a tool to assess

their students' environmental knowledge to work more proficiently towards environmental literacy.

5. Implications and Conclusion

5.1 Challenges for Education

Once gaps in content have been identified using this assessment (AEILESS), the instructor is then left to address any basic knowledge acquisition insufficiencies. There are many different academic resources and materials available covering environmental topics in life science, physical science and earth systems science for K-12, but there are fewer available for higher education. In other words, changes to curriculum and instruction in higher education will require time to adapt K-12 resources and materials. Very little research has been done examining the quality of environmental texts and curriculum in the United States. Erdogan (2009) has shown that the curricula in Bulgaria and Turkey are lacking in the behavior (action) component of EL, but are strong in knowledge. This may also be the case in American textbooks and curricula. It is up to the instructor to decide whether he or she wants to focus on broad environmental concepts the students are struggling with or whether it would be better to focus on an individual topic within the sub-domain, and then decided what pedagogical approach should be taken to emphasize a particular concept or domain.

Using the Science Standards, each item on the instrument can be traced back to a specific skill the students should master. For example, if only 9% of students answer item one correctly, this question falls under the high school physical science standard. More specifically, the concept and skill the student should master with this question is, *Energy exists in many forms such as mechanical, chemical, electrical, radiant, thermal and nuclear, that can be quantified and experimentally determined* ("Colorado academic standards," 2009). This topic can be referenced in, for example, the text, *Environment: The Science Behind the Stories*. More specifically, in chapter 4: From Chemistry to Energy to Life (Withgott, 2009). Each question has a specific topic the instructor can focus on by reviewing the Science Standards. Another source is the AAAS website, which provides a plethora of concepts and ideas to cover under each content area.

However, this means that a) educators need to be familiar with the K-12 content science standards, and b) have the luxury of time to make these connections and change their teaching as well as assessment.

5.2 Limitations of Assessment

Environmental knowledge can come from sources outside of education, such as family, media, peers and personal experience. With the multitude of factors impacting an individual's environmental literacy, it is nearly impossible to claim that literacy is a direct result of education. There is no question, however, that literacy is greatly impacted by the quality of education.

No qualitative questions were included in the assessment as a means of testing whether students could answer open-ended questions using a combination of sciences' knowledge and thought. Qualitative questions require appropriate response mechanisms, giving insight to the respondent's attitude and possibly their individual actions and behaviors. In reality the environment is a holistic system, therefore the physical sciences and the social sciences should not be considered in isolation from one another. Students should be given opportunities to integrate, synthesize, and apply knowledge from the different content areas. In higher education, however, students are typically assessed by separating science from social studies, reading, writing, math, communicating and health. Future adaptations to the AEILESS tool should include, at the very least, social studies.

Rather than add an environmental content section to the standards, the CDE have incorporated environmental topics into the biology standards. This integration has been openly accepted because the topics are profoundly interconnected. Biology and environmental science should be integrated in education, as should chemistry and earth sciences. Combined in education, they create a very strong candidate for the science field. A student who is able to make interdisciplinary connections between the sciences is more likely to solve complex biological

problems (Roth 1976; Stapp, 1976; Brogdon & Rowsey, 1977; Schneider 1997; Feig 2004). They have an advantage when using science tools from multiple fields. Specialization is not lost, but a new perspective, is gained. Unfortunately, the Cartesian-Newtonian concept of scientific modernism, with its fragmentation of the sciences, has only been reinforced throughout the decades. Environmental science integration and assessment is most likely an anomaly within the dominant educational paradigm. Hopefully the importance of interdisciplinary teaching and learning in the sciences finds a way into assessment practices in higher education.

The Colorado Environmental Literacy plan includes competencies from, not just the Science content area, but also from Social Studies, including standards in History, Geography, Economics and Civics. Social studies are equally as important as the sciences when assessing environmental literacy. It is important that students, not only have knowledge about ecological processes and human impacts, but that they become active citizens interested in progressing their communities and government. Students need a sense of civic and personal responsibility to the environment. They must understand the social, economic and environmental conditions and injustices of humanity. It is a combination of ecological and social knowledge and experiences that contour students' attitudes, values and behavior. A second assessment should be created to cover the environmental social studies content such as population growth, environmental equity, environmental history, migration, urbanization and development.

The greatest limitation of the assessment is that it only assesses knowledge and skills of individuals. Environmental literacy is influenced by more than these two components, as you can see below, in Figure 5.1.

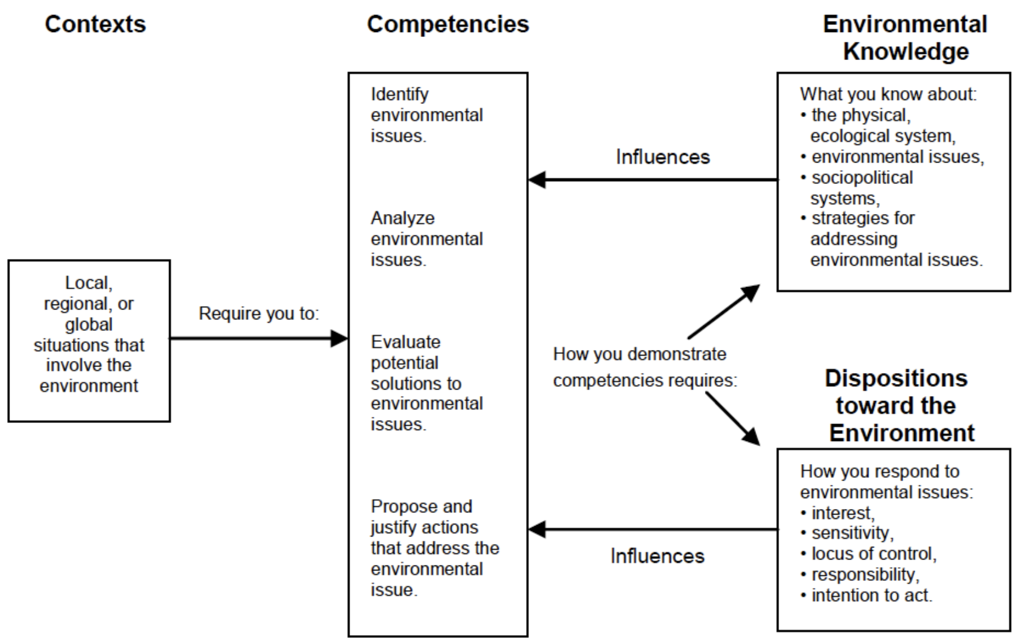

Figure 5.1 PISA Framework for Assessing Environmental Literacy. The PISA 2015 framework emphasizes that competencies are influenced by both environmental knowledge as well as one's disposition toward the environment.

A vital element in achieving environmental literacy is that an individual not only has the knowledge of ecological and social systems, issues and strategies, but that they have a positive disposition towards the environment. Future assessments of scientific knowledge or environmental literacy might be combined with measures of behavior, attitudes and dispositions toward the environment.

5.3 Dispositions towards the environment

Many individuals believe that they are environmentally literate yet when asked to describe nature they portray places absent from any human interference (Vining 2008). Others do not believe they are a part of nature at all. Humans have made an effort to control nature since the beginning of their existence. Some examples are the Agricultural Revolution the Industrial Revolution and the Technological Revolution. Although we have entered what is known as the Green Revolution, a continuation of technological advancements, humans seem to have lost their connection with their natural world. In nations that at are less developed and less industrialized, we can see symbiotic relationships with nature, reflecting an image of early Americans, pre-technological advancement. (Campbell 1983; Eliade 1964).

The fact that many Americans do not acknowledge they are a part of nature may influence their environmental values and thus their actions towards the Earth (Dutcher 2007). Instead of respecting and seeing the value in indigenous ways, western cultures are continually pushing economic development and, indirectly, environmental destruction on less industrialized countries (Apffel-Marglin 1990, Mander 2006). The Dominant Social Paradigm (DSP) reinforces the view that western civilization has the most superior knowledge and culture. It also emphasizes that other nations' resistance to conform and develop stems from ignorance. However, Apffel-Marglin (1990) has shown that it is not actually superior cognitive power that enables modern knowledge to trump traditional knowledge, but economic and social prestige associated with western cultural history over the past 500 years. For many western societies, it is a difficult concept to grasp, that poor, indigenous people could be more environmentally literate.

Those with environmental concerns are challenging the existing paradigm. Kilbourne (2002) has shown that the greater one believes in and values the DSP, their expressed concern for the environment decreases, showing an inverse relationship. Thanks to authors such as Thomas S. Kuhn, whose writings in the 1960's covered topics such as paradigm anomalies, crisis and shifts,

scientists began to exhibit different attitudes toward existing paradigms and started questioning their nature. Dunlap and Van Liere (1978) developed the New Environmental Paradigm (NEP) Scale to measure an individual's proenvironmental orientation. It's revision, the new ecological paradigm scale (Dunlap, Van Liere, Mertig, & Jones, 2000), was created to measure environmental attitudes, influenced by fundamental values and beliefs. Many assessments have since been created to assess the same issue (including Milfont 2009). As stated in Figure 5.1, it is my hope that learners demonstrate not only an increase in knowledge but also a shift in disposition from DSP to NEP.

5.4 Environmental values and beliefs

According to Sean Esbjörn-Hargens (2009) western societies have six basic, heavily weighted values. In decreasing value they are: security, power, principle, profit, people and planet. It is ironic to me that people and planet would be at the bottom end of the scale. Farrior (2005) categorized environmental values into three broad categories: egoistic concerns, social alturuistic concerns and biospheric concerns. Egoistic concerns focus on one's own health, quality of life, prosperity and convenience. The social-alturuistic concerns focus on other people, such as children, family, community and humanity. Lastly, the biospheric concerns focus on the well being of non-human, living organisms such as flora and fauna. Centuries of efforts have been made to transform society's view of human dominion and the conquest of nature, falling under egoistic concerns. Although there have been a few environmentalist throughout history, it was not until the 21st century that respect for the environment was brought about through a "deep-seated realization of the fact that we and all other entities are aspects of a single unfolding reality" (Fox, 1990).

Many writers and experts in the field of EE believe that environmental behavior is the ultimate goal of EE (eg. Childress and Wert 1978; Harvey 1977; Hungerford and Peyton 1976;

Hungerford, Peyton, and Wilke 1980; Rubba and Wiesenmayer 1985; Stapp 1978). After all, an individual's behaviors reveal whether they are considered operational in their environmental literacy. "Environmental literacy should be defined . . . in terms of observable behaviors. That is, people should be able to demonstrate in some observable form what they have learned — their knowledge of key concepts, skills acquired, disposition toward issues, and the like" (Daudi, 1997). Western culture has, however, shown that an individuals' behavior is often disconnected from the attitudes or beliefs they hold. This term has been coined the attitude-behavior gap, that is, people show concern for cars and factories releasing toxins and pollutants into the environment, yet they continue to drive their cars and buy products that are not made sustainably (Campbell 1963).

Allport (1935) defined an attitude as "a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related". Behavior, on the other hand is the manner of conducting ones self. Although attitudes were once considered a direct precedent to behavior, this is no longer an accepted idea among social psychologists (Greve, 2001).

Simply because an individual answers every question on the assessment correctly does not mean that s/he consistently engages in environmental behaviors. "Individual and societal environmental behavior belies the assumption that behavioral change follows directly from development of necessary knowledge and skills" (Iozzi, 1989). Ultimately, there are many factors that have been found to influence pro-environmental behavior including: demographic factors, external factors (e.g. institutional, economic, social and cultural), and internal factors (e.g. motivation, pro-environmental knowledge, awareness, values, attitudes, emotion, locus of control, responsibilities and priorities) (Kollmuss, 2002). Imagine environmental knowledge as the tip of an enormous iceberg. The iceberg itself is environmental literacy, which necessitates the creation of multiple assessments corresponding to each of its 'under water' components, and not exclusively the 'visible' environmental knowledge.

6. Epilogue

Personally, I have found my place in Environmental Education. I will undoubtedly spend the rest of my life teaching courses on systems thinking, multicultural environmental communication, atmospheric science, ecology, green technology and sustainability. It is my hope that our future generations will have a powerful connection to their living and nonliving surroundings, have a strong sense of community, leadership and advocacy, and that they are able to use their environmentally literate minds to protect and restore the Earth's balance. My hope is that the instrument I have created, *Assessing the Environmental Literacy of Intro Environmental Science Students,* will point educators in the right direction and give students a more focused and personal curriculum and in the end, a meaningful educational experience for all.

APPENDIX A.

Geographic Dispersion of survey respondents

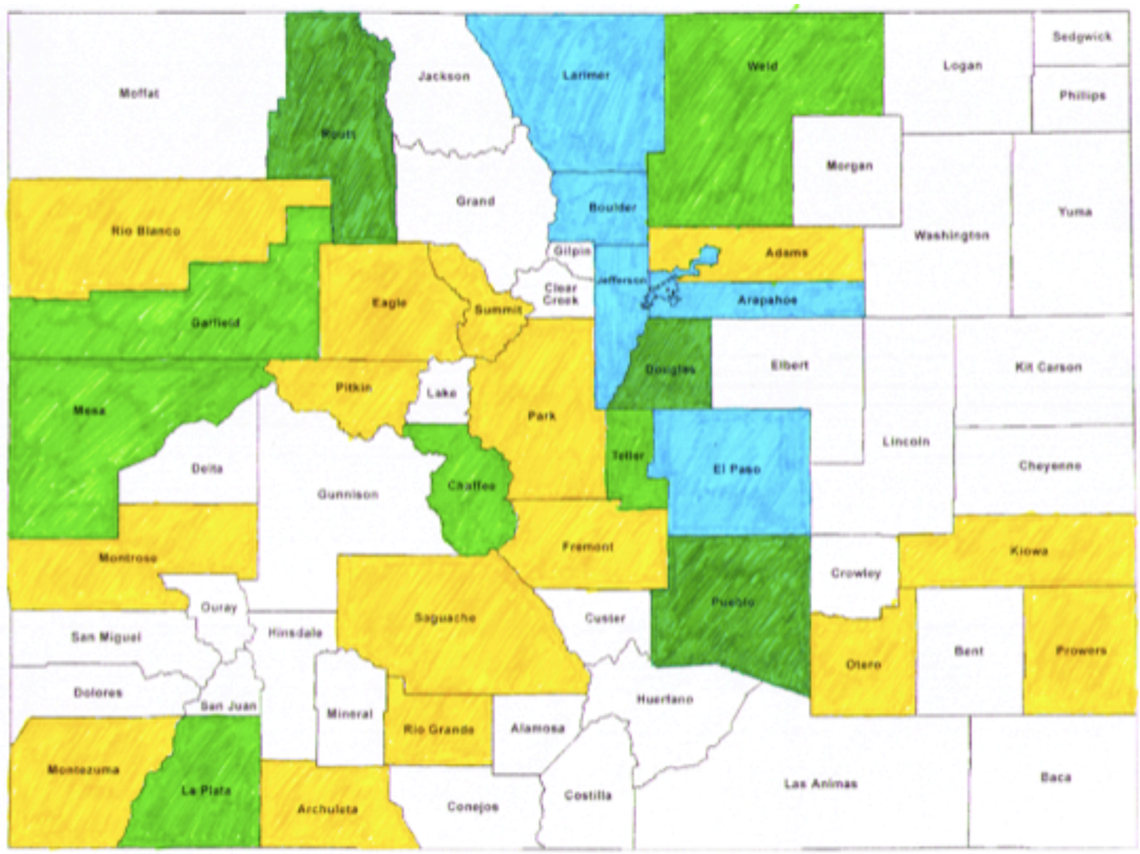

Figure 2.1 Geographic dispersion of survey respondents. The map illustrates the geographic dispersion of respondents who completed the survey in Colorado. Yellow represents 1-2 respondents, Light Green represents 3-5 respondents, Dark Green represents 6-15 respondents and Blue represents 15+ respondents (Navin, 2010).

APPENDIX B.

Introduction to Environmental Science Syllabus

ENVS 1042: Introduction to Environmental Science
Monday and Wednesday 12:30 to 1:45 and 2:00 – 3:15
Tentative Syllabus

Instructor: Dr. Jon Barbour
Department of Geography and Environmental Sciences
Office: North Classroom 3622.
Phone: 303-556-4520
Email: jon.barbour@cudenver.edu
Office hours: Monday and Wednesday 8:00 – 9:00 a.m. or by appointment.
Course Information Website: http://clasfaculty.ucdenver.edu/jbarbour/

TEXT Withgott and Brennan. Environment: The Science Behind the Stories 3rd Edition, Pearson Education Inc. San Francisco

PREREQUISITES: There are no formal prerequisites. Some basic math and science skills, as well as familiarity with the use of library resources will required.

COURSE DESCRIPTION: The major objective of this course is to provide students with the tools and background information required to reasonably understand and discuss environmental issues facing current and future generations. The course also serves as an introductory course for the Earth & Environmental Sciences (EES) degree option within Geography. This course will cover basic biology, chemistry, physics, and ecological science that determine the Earth's environment in which we live today.

MEASURABLE STUDENT LEARNING OBJECTIVES:

Understanding of:

1. The basic science disciplines that are involved in Environmental Science.
2. Functioning of the major systems and processes that are active in the Earth's environment.
3. What is sustainability and what are the factors involved in achieving it.
4. How we as human society may achieve and maintain both energy and environmental sustainability.

Technical and analytical skills:

1. Basic research skills in researching, compiling and organizing information from libraries, the world wide web, scientific journals and databases.
2. Synthesize and analyze information from different sources and points of view.

TENTATIVE COURSE SCHEDULE:
Wednesday 1/19 Class introduction
Monday 1/24 An Introduction to Environmental Science (Chap 1)
Wednesday 1/26 Environmental Ethics and Economics (Chap 2)
Monday 1/31 Environmental Policy (Chap 3)
Wednesday 2/2 From Chemistry to Energy to Life (Chap 4)

Figure 3.2 ENVS 1042: Introduction to Environmental Science Syllabus

Monday 2/7 Evolution, Biodiversity, and Population Ecology (Chap5)
Wednesday 2/9 Species Interactions and Community Ecology (Chap 6)
Monday 2/14 Environmental Systems and Ecosystem Ecology (Chap 7)
Wednesday 2/16 Human Population (Chap 8)
Monday 2/21 Soil and Agriculture (Chap 9)
Wednesday 2/23 Agriculture, Biotechnology, and the Future of Food (Chap 10)
Monday 2/28 Sustaining Biodiversity (Chap 11)
Wednesday 3/2 Review for Mid Term Exam
Monday 3/7 **Mid Term Exam**
Wednesday 3/10 Return and Review Exam
Monday 3/14 Resource Management (Chap 12)
Wednesday 3/16 Urbanization and Creating Livable Cities (Chap 13)
Monday 3/21 **NO CLASS SPRING BREAK**
Wednesday 3/23 **NO CLASS SPRING BREAK**
Monday 3/28 Environmental Health and Toxicology (Chap 14)
Wednesday 3/30 Freshwater Resources (Chap 15)
Monday 4/4 Marine and Costal Systems (Chap 16)
Wednesday 4/6 Atmospheric Science and Air Pollution (Chap 17)
Monday 4/11 Global Climate Change (Chap 18)
Wednesday 4/13 Fossil Fuels, Their Impacts, and Energy Conservation (Chap 19)

Monday 4/18 Conventional Energy Alternatives (Chap 20)
Wednesday 4/20 New Renewable Energy Alternatives (Chap 21)
Monday 4/25 Waste Management (Chap 22)
Wednesday 4/27 Sustainable Cities (Chap 23)
Monday 5/2 Make up day for snow etc.
Wednesday 5/4 **Review for Final Exam**

FINAL EXAM (Comprehensive) According to Finals Schedule

PLEASE NOTE: You must pass both lab and lecture sections to pass the course, i.e. you must obtain at least 60% of the points in lab (180) and lecture (240) to pass. Also, you must pick up your mid-term exam when handed back or 10 points will be deducted from your exam.

Total points: 700 points distributed as follows:

Exams:

Mid Term Exam 100
Comprehensive Final Exam 200

Quizzes:

There will be 5 unannounced quizzes during the term.
Each will be 20 points for a total of 100 points.

Total points from labs
300

You must register for a lab section as part of this course. The lab points are entirely determined by the lab instructor.

Figure 3.2 (Continued)

APPENDIX C.
AELIESS assessment instrument

Title: Assessing the Environmental Literacy of Intro Environmental Science Students

Date: 1/18/2012

Student Information: Gender: male female Ethnicity: ________________

Age: ________

Did you graduate High School? Yes/No Are you an ENVS major? Yes/No

How many years of K-12 was attended in Colorado? ____________

DIRECTIONS: Multiple-Choice: please circle one answer for each question.

1. Consider the following situations:
   Situation 1: A battery is used to power a cell phone.
   Situation 2: The sun shines on a plant.
   Is energy being transferred in either of these situations?

A. Energy is transferred in both situations.
B. Energy is NOT transferred in either situation.
C. Energy is transferred when a battery is used to power a cell phone, but energy is NOT transferred when the sun shines on a plant.
D. Energy is transferred when the sun shines on a plant, but energy is NOT transferred when a battery is used to power a cell phone.

2. The thermal energy of an object depends on which of the following?

A. Both the temperature of the object and the material it is made of
B. The temperature of the object but not the material it is made of
C. The material the object is made of but not the temperature of the object
D. Neither the temperature of the object nor the material it is made of

3. Which of these is a renewable resource?

A. Wood, because trees grow again
B. Gold, because more can be made very easily
C. Petroleum, because it can be refined into gasoline
D. Coal, because more can be made in about 100 years

4. Which energy transformation occurs first in a coal-burning power plant?

A Chemical energy to thermal energy
B Thermal energy to mechanical energy
C Thermal energy to electrical energy
D Mechanical energy to electrical energy

5. Coal, petroleum, and natural gas found underground in certain parts of Earth are primarily formed from which process?

A. Decay of radioactive elements
B. Collision of tectonic plates in earthquakes
C. Transformation of dead plants and animals under heat and pressure
D. Intrusion of water into the soil that breaks up rocks and minerals

Figure 3.3 AELIESS assessment instrument6. Which of the following is TRUE about the extinction of species?

A. Very few species have ever become extinct. Most continue to exist.
B. There have been extinction events in which many species became extinct at about the same time. Aside
from these, extinction is very rare.
C. Up until recently, species rarely became extinct. Humans have caused the majority of extinctions.
D. Many species have become extinct throughout the history of life on earth.

7. Which of the following is TRUE about how changes can happen to the physical environment of earth?
A. Changes can happen suddenly or gradually.
B. Changes can happen suddenly but not gradually.
C. Changes can happen gradually but not suddenly.
D. Changes can happen neither gradually nor suddenly because the environment does not change.

8. Which of the following is food for a plant?
A. Sugars that a plant makes
B. Minerals that a plant takes in from the soil
C. Water that a plant takes in through its roots
D. Carbon dioxide that a plant takes in through its leaves

9. Because they are rapidly being cut down, the rain forests today are endangered ecosystems. How might widespread destruction of the rain forests affect other ecosystems in the world?
A. by increasing the amount of available soil
B. by reducing the amount of available oxygen
C. by increasing the diversity of plant and animal life
D. by reducing the amount of available carbon dioxide

10. When the environment changes more quickly than a species can adapt, the species may become
A. extinct
B. diverse
C. dominant
D. overpopulated

11. The diagram below shows the feeding relationships between populations of plants and animals in an area. The arrows point from the organisms being eaten to the organisms that eat them.

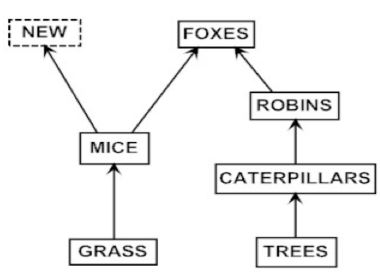

Figure 3.3 (Continued)

A new species that eats only mice becomes part of this food web, greatly reducing the number of mice in this area. Using only the relationships between the plants and animals shown in the diagram, what effect would the new species have on the caterpillar population if the number of foxes stays the same?

A. The number of caterpillars would increase.
B. The number of caterpillars would decrease.
C. The number of caterpillars would stay the same.
D. There is not enough information to tell what would happen to the number of caterpillars.

12. Which of the following statements about competition between animals is TRUE?
A. Competition may involve two lions fighting over prey but not two cows eating grass in the same field.
B. Competition may involve two birds fighting over a nesting site but not one bird placing its eggs in the nest of another.
C. Competition may involve two birds fighting over a nesting site, two lions fighting over prey, or one bird placing its eggs in the nest of another but not two cows eating grass in the same field.
D. Competition may involve two birds fighting over a nesting site, two lions fighting over prey, one bird placing its eggs in the nest of another, or two cows eating grass in the same field.

13. As the energy needs for Colorado increase, new sources of energy are required to replace or supplement the nonrenewable sources of energy now in use.
Two sources of energy that are renewable and available in Colorado are —
A. natural gas and wind power
B. coal and hydropower
C. petroleum and solar power
D. wind power and solar power

14. Which form of energy strikes the best balance between energy production and environmental impact?
A) solar
B) tidal
C) nuclear
D) algae biofuel

15. The greenhouse effect presents some concern to humans but it is also an important part of Earth's ecosystem. Why is this?
A. It makes Earth habitable by cooling its atmosphere.
B. It makes Earth habitable by warming its atmosphere.
C. It helps screen out harmful radiation from the sun.
D. It prevents carbon dioxide from escaping Earth's atmosphere.

16. Which of these has the LEAST influence on an area's climate?
A. latitude
B. elevation
C. soil conditions
D. adjacent large bodies of water

Figure 3.3 (Continued)

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Answers	A	A	A	A	C	D	A	A	B	A	A	D	D	D	B	C

Figure 3.3 (Continued)

APPENDIX D.
AELIESS questions chosen using Colorado academic standard outline

Table 2.1 AELIESS Questions chosen using the Colorado Academic Standard's outline of critical concepts and skills for K-12 ("Colorado academic standards," 2009).

Questions 1-3: Physical Science. Were created using:
Content Area: ScienceGrade Level Expectations: High SchoolStandard: 1. Physical Science Concepts and skills students master:
1. Energy exists in many forms such as mechanical, chemical, electrical, radiant, thermal, and nuclear, that can be quantified and experimentally determined
Questions 4-13: Life Science. Were created using:
Content Area: ScienceGrade Level Expectations: High SchoolStandard: 2. Life Science; Content Area: ScienceGrade Level Expectations: Sixth GradeStandard: 2. Life Science
Concepts and skills students master:
2. Matter tends to be cycled within an ecosystem, while energy is transformed and eventually exits an ecosystem
3. The size and persistence of populations depend on their interactions with each other and on the abiotic factors in an ecosystem
4. The energy for life primarily derives from the interrelated processes of photosynthesis and cellular respiration. Photosynthesis transforms the sun's light energy into the chemical energy of molecular bonds. Cellular respiration allows cells to utilize chemical energy when these bonds are broken.
5. Changes in environmental conditions can affect the survival of individual organisms, populations, and entire species
6. Organisms interact with each other and their environment in various ways that create a flow of energy and cycling of matter in an ecosystem

Table 2.1 (Continued)

Questions 14-16: Earth Systems Science. Were created using:
Content Area: ScienceGrade Level Expectations: High SchoolStandard: 3. Earth Systems Science; Content Area: ScienceGrade Level Expectations: Eighth GradeStandard: 3. Earth Systems Science
Concepts and skills students master:
1. Climate is the result of energy transfer among interactions of the atmosphere, hydrosphere, lithosphere, and biosphere
2. There are costs, benefits, and consequences of exploration, development, and consumption of renewable and nonrenewable resources
3. Earth has a variety of climates defined by average temperature, precipitation, humidity, air pressure, and wind that have changed over time in a particular location

APPENDIX E.

Studies assessing aspects of EL

Table 3.1 A selection of studies that assess instructional effectiveness concerning aspects of EL.

(Hungerford, 2005, p.76-77)

A Selection of Studies Which Assessed Instructional Effectiveness Concerning Aspects of Environmental Literacy

Study	Validity/ Reliability	Independent Variable	Subject Grade/Age	Dependent Variable	Significant Effect
Adams et al., 1987	No/No	Biology course	High School	Attitude	+
Armstrong & Impara, 1991	Yes/Yes	Supplemental instruction	5, 7	Attitude, Ecological Knowledge	- Mixed
Bennet, 1982	Yes/Yes	Social studies program	Junior high school	Socio-Political Knowledge	+
Benton, 1993	No/Yes	Environmental management course	College	Attitude, Environmental Issue Knowledge, Additional Determinants, Responsible Behavior	+ + + +
Birch & Schwaab, 1983	Yes/Yes	Instructional unit	7	Attitude, Environmental Issue Knowledge	+ +
Brothers et al. , 1991	Yes/No	Television documentary	Adults	Attitude Environmental Issue Knowledge	+ +
Burrus-Bammel & Bammel, 1986	Yes/Yes	Residential camp	16 - 20 years	Attitude Ecological Knowledge	+ +
Collins et al., 1978	No/Yes	Field trip with activities	4,5,6	Attitude	+
Crater & Mears, 1981	No/No	Instructional unit	8	Attitude, Environmental Issue Knowledge	+ +
Dresner, 1989/90	No/No	Simulation game	College	Attitude, Additional Determinants	- -
Dunlop, 1979	Yes/Yes	Simulator	Teachers	Attitude	-
Fortner & Lahm, 1990	Yes/Yes	Instruction (in-classroom information and site visit)	4, 5	Attitude, Ecological Knowledge	- +
Fortner & Lyon, 1985	Yes/No	Television documentary	Adults	Attitude, Ecological Knowledge	+ +
Geller, 1981	No/No	Workshop	Adults	Attitude, Additional Determinants, Responsible Behavior	+ + -
Glass, 1981	No/Yes	Workshop	Teachers	Attitude, Environmental Issue Knowledge	+ +
Jaus, 1982	No/Yes	Instruction	5	Attitude	+
Jaus, 1984	Yes/Yes	Instruction	3	Attitude	+
Jordan, et al., 1986	Yes/No	Residential camp	High School	Socio-Political Knowledge, Responsible Behavior	+ +
Kidd et al., 1978	No/No	Forest camp	16-20 years	Attitude, Ecological Knowledge	+ +
Kinsey & Wheatley, 1984	No/No	Environmental studies course	College	Attitude	Mixed
Lawrenz, 1985	No/Yes	Workshop	Teachers	Attitude	+
Marshdoyle et al., 1982	No/No	Field trip	4, 5, 6	Ecological Knowledge	+
Mills et al., 1985	Yes/Yes	Computer simulation	Teachers	Attitude, Environmental Issue Knowledge	+ +

Table 3.1 (Continued)

Table continued: A Selection of Studies Which Assessed Instructional Effectiveness Concerning Aspects of Environmental Literacy

Study	Validity/ Reliability	Independent Variable	Subject Grade/Age	Dependent Variable	Significant Effect
Milton et al, 1995	No/Yes	Park/school program	5	Attitude, Ecological Knowledge	- +
Pomerantz, 1986	Yes/No	Children's nature magazine	5	Ecological Knowledge	+
Ramsey & Hungerford, 1989	Yes/Yes	Instruction (investigation and action)	7	Attitude, Socio-Political Knowledge, Cognitive Skills, Additional Determinants, Responsible Behavior	- + + +
Ramsey, 1993	Yes/Yes	Instruction (investigation and action)	8	Attitude, Socio-Political Knowledge, Cognitive Skills, Additional Determinants, Responsible Behavior	- + + Mixed +
Ramsey et al., 1981	No/No	Instruction (investigation and action)	8	Socio-Political Knowledge, Responsible Behavior	+ +
Ross & Driver, 1986	No/No	Youth Conservation Corps program	15 -18 years	Attitude, Environmental Issue Knowledge, Responsible Behavior	+ + +
Shepard & Speelman, 1985/86	No/No	Outdoor education program	9-14 years	Attitude	-
Simmons, 1984	No/No	Presentation methods (on-site vs. simulated visit)	Adults	Attitude, Environmental Issue Knowledge	+ +
Smith-Sebasto, 1995	Yes/Yes	Environmental studies course	College	Socio-Political Knowledge, Cognitive Skills, Additional Determinants, Responsible Behavior	+ + + +
Stapp et al., 1983	No/No	Middle school curriculum	6, 7	Attitude, Environmental Issue Knowledge, Cognitive Skills Additional Determinants	+ + + +
Strickland et al. 1983/84	Yes/Yes	Instruction	3-5 years	Environmental Issue Knowledge	+
Trent, 1978	No/Yes	Workshop	Teachers	Attitude, Environmental Issue Knowledge	- +
Volk & Hungerford, 1981	No/Yes	Instruction	8	Environmental Issue Knowledge, Cognitive Skills	+ +
Westphal & Halverson, 1985/86	No/No	Workshop	Adults	Environmental Issue Knowledge, Responsible Behavior	+ +
Wilson & Tomera, 1980	Yes/Yes	Supplemental case study	High school	Attitude	-

APPENDIX F.

EL contexts and distributions

Table 3.2 Contexts for environmental literacy. The following table was taken from the PISA environmental literacy framework and used to develop items on AELIESS (Hollweg et al., 2011).

	Local	Regional	Global
Biodiversity	Flora and fauna	Endangered species, habitat loss, exotic invasive species	Ecological sustainability, sustainable use of species
Population Growth	Growth, birth/death, emigration, immigration	Maintenance of human population, population distribution, over population	Population growth and its social, economic, and environmental consequences
Natural Resources	Personal consumption of materials	Production and distributions of food, water, energy	Sustainable use of renewable and non-renewable resources
Environmental Quality and Health	Impact of use and disposal of materials on air and water quality	Disposal of sewage and solid waste, environmental impact	Sustainability of ecosystem services
Natural Hazards and Extreme Weather	Decisions about housing in areas vulnerable to flooding, tidal and wind damage	Rapid changes (e.g. earthquakes), slow changes (coastal erosion), risks and benefits	Climate change, extreme weather events
Land Use	Conservation of agricultural lands and natural areas	Impact of development and diversion of water, watersheds, and flood plains	Production and loss of topsoil, loss of arable land

Table 3.3 Distributions of contexts: The items that include this context, as well as the percentage of each context represented in the assessment AELIESS.

Context	Biodiversity	Natural Resources	Environmental Quality and Health	Natural Hazards and Extreme Health	Land Use
Items including context	6, 8, 9, 10, 11, 12	1, 2, 3, 4, 5, 13, 14	7, 13, 14, 15	7, 10, 15	9, 16
% Items containing context	37.5	43.75	25	18.75	12.5

APPENDIX G.

IRB approval letter

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FWA00005070 [FWA]

University of Colorado Hospital
Denver Health Medical Center
Veteran's Administration Medical Center
The Children's Hospital
University of Colorado Denver
Colorado Prevention Center

Certificate of Exemption

08-Dec-2011

Investigator:	Randi Hogden
Sponsor(s):	
Subject:	COMIRB Protocol 11-1474 Initial Application
Effective Date:	06-Dec-2011
Anticipated Completion Date:	06-Dec-2014
Exempt Category:	1
Title:	Assessing The Environmental Literacy Of Intro Environmental Science Students

This protocol qualifies for exempt status. Periodic continuing review is not required. For the duration of your protocol, any change in the experimental design/content of this study must be approved by the COMIRB before implementation of the changes.

The anticipated completion date of this protocol is 06-Dec-2014. COMIRB will administratively close this project on this date unless otherwise instructed either by correspondence, telephone or e-mail to COMIRB@ucdenver.edu. If the project is closed prior to this date, please notify the COMIRB office in writing or by e-mail once the project has been closed.

You will be contacted every 3 years for a status report on this project.

Any questions regarding the COMIRB action of this study should be referred to the COMIRB staff at 303-724-1055 or UCHSC Box F-490.

Review Comments:

This Exempt Approval Includes - This submission was submitted as Expedited but was determined to qualify as Exempt (all attachments are n/s with the Exempt approval. Attachment O is also N/A) - v. 12/1/2011:-

Application
Information Sheet

Affiliated Site - Downtown Denver Campus

Sincerely,

UCD Panel S

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